USAAVLABS TECHNICAL REPORT 65-59

UH-1D AIRCREW ARMORED SEAT CRASH SURVIVAL ANALYSES

PRELIMINARY REPORT

By

J. L. Reed
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SUMMARY

This report contains the results of preliminary crash survival analyses of a UH-1D aircrew armor seat. The data used in this study were developed from manufacturers' drawings, military specifications, and other sources. Further effort is required to determine the quantitative effects of the incorporation of an aircrew armor system into the existing UH-1D seat frame and restraint system. However, preliminary analyses and tests indicate that the new system, as configured, will contribute to a marginal crash survival condition for the aircrew occupants. Therefore, a program of redesign should be given serious consideration.

CONTENTS

ILLUSTRATIONS

SYMBOLS

C	column compression load, lb
C_v	vertical component of column compression load, lb
$F_{b\ max}$	maximum allowable bending stress in seat leg, psi
F_i	force, lb (i indicates many different conditions)
F_{ty}	tensile yield strength, psi
L	contact length of track, in
L_l	lateral load, lb
L_f	forward load factor
L_{lf}	lateral load factor
M	bending moment in beam, in-lb
M_i	moments about any given point described by i, in-lb
M_p	plastic hinge moment, in-lb/in
P_f	horizontal inertia load, lb
P_s	side inertia load, lb
P_v	vertical inertia load, lb
R	seat belt reaction load, lb
R_a	forward reaction track load, lb
R_b	aft reaction track load, lb
R_f	horizontal load shear reaction at base of seat leg, lb
R_l	rearward load, lb

R_{lf}	rearward load factor
R_s	side load shear reaction at base of seat leg, lb
$R_{s\ max}$	maximum shear load allowable in seat bracket, lb
$R_{t\ max}$	maximum tensile load allowable in seat bracket, lb
R_x	horizontal seat belt reaction, lb
R_y	vertical seat belt reaction, lb
R_z	lateral seat belt reaction, lb
S	section modulus, in^3
$S_{b\ max}$	maximum allowable seat belt load, lb
T	tensile force at base of aft seat leg, lb
T_a	tensile force transmitted through tension bolt at top of aft leg, lb
V	shear load in beam, lb
V_1	vertical load, lb
V_{lf}	vertical load factor
W_c	occupant weight, lb
W_s	seat weight, lb
X	horizontal direction
Y	vertical direction
Z	lateral direction
α	seat belt rotation angle measured in top view, degrees
β	seat belt rotation angle measured in rear view, degrees
Σ	sum
Δ	incremental
ϕ	direction angle measured in plane of rotation, degrees

INTRODUCTION

During April 1965, the U. S. Army Aviation Materiel Command (USAAVCOM) and the U. S. Army Materiel Command UH-1 Project Manager's Field Office acted upon an urgent requirement to design an aircrew protection system for the UH-1D helicopter. The UH-1 field office developed an integrated design review team from the following agencies:

U. S. Army Aviation Board for Accident Research
U. S. Army Aviation Materiel Command
U. S. Army Aviation Test Board
U. S. Army Aviation Materiel Laboratories
11th Air Assault Division

The design effort for this program was conducted under a contract with the Aerojet-General Corporation, Azusa, California. The contractor's efforts were supervised and controlled by the UH-1 field office. All other agencies participated as consultants.

The contractor developed an initial mock-up of a system to provide ballistic protection for the pilot and copilot stations. After the system was reviewed by the armor review team, comments were furnished the contractor, who, in turn, developed appropriate design changes. A second meeting was held at which time the design was again reviewed. Four prototype seats developed from actual aircrew armor material were examined. Static load tests of the seat were conducted by the Hardman Tool and Engineering Company to determine the structural capability of the seat and frame. Documentary photographs and other data were developed on each of the program activities. A limited flight test evaluation was conducted using a UH-1D that was furnished by the 11th Air Assault Division.

The objective of this program was to design an armored seat shell to fit into the existing UH-1D and UH-1B seat frame. Figure 1 shows a view of the current UH-1D seat (FSN 1680-052-4716). This seat consists of a lightweight tubular steel frame and seat structure covered with a grid of nylon mesh. The complete seat weighs from 26 to 30 pounds.

In order to minimize retrofit problems, the armored seat shell was designed to be attached at the existing seat attachment points. The armored shell is connected to the seat through 16 ANC-3 bolts and nuts. Because the armored seat bucket was wider than the existing tubular seat frame, an eccentric fitting was developed to attach the outside column struts (see Figure 2). The column strut was redesigned by the contractor to accept the additional load redistribution. The shoulder harness reel was removed from the floor installation and mounted on the seat frame cross tubes. The purpose of this change was to facilitate the in-flight removal of the seat in order to provide medical care to injured crewmen. The existing reel location prohibits the seat from being rolled back.

The armored shell was fabricated from Aerojet STARMAT armor material, which consists of aluminum (2024-T4) backing material to which Al_2O_3 tiles are bonded. The tiles face away from the seat occupant's body and the aluminum backing material faces inside the seat. The basic seat shell is fitted together by lapped structural joints and connected by bolts tapped into the aluminum backing material. A sliding panel assembly is mounted on the door side of each seat (see Figure 3). This panel provides body coverage for the occupant and may be retracted for ease of ingress or egress (see Figure 4).

The substitution of an armored seat shell for the existing UH-1 nylon and tubular frame seat decreases the seat allowable load factor. By adding additional weight to the seat, the strength of the supporting structure is adversely reduced. A technical discussion of the effects of this modification appears in Appendix I.

Crash survival areas are discussed in the following sections to provide a brief analysis of the restraint system components. Detailed information is available in Appendixes I and II.

Static tests that were conducted on the seat frame indicated that the new seat frame load factors were approximately 12 to 13G. The original load factor for the seat was 15G; however, this was for an ultimate load condition (that is, no failure of any member, although permanent set is allowable). The actual static failure load factor for the tubular seat is much higher - approximately 21G. The armored seat shell therefore contributes to a reduction in seat safety.

The purpose of this report is to describe the reduced crashworthiness of the seat caused by the presence of the aircrew armor and to develop suggested engineering changes to correct such deficiencies.

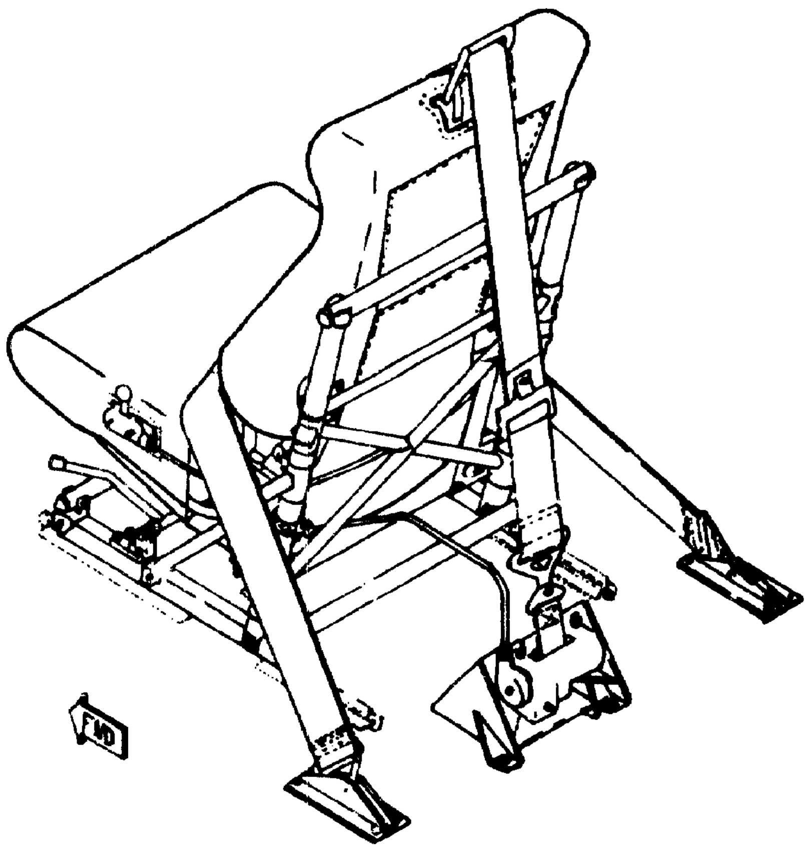

Figure 1. UH-1D Pilot and Copilot Seat Assembly.

Figure 2. Seat Back Showing Eccentric Column Fittings and Relocation of Shoulder Harness Reel.

Figure 3. Copilot's Seat Showing Armor Panel in Full Forward Position.

Figure 4. Pilot's Seat With Armor Side Panel in Aft Position. (Note that method of egress is adequate.)

CONCLUSIONS

It is concluded that:

1. The preliminary load and stress analyses of the seat frame and personnel restraint system compare favorably with the static test results.

2. The seat frame legs and connection fittings should be strengthened through redesign. The basic frame requires additional strengthening in order to increase the allowable seat load factor.

3. The relocation of the shoulder harness on the back of the seat frame is not a satisfactory design solution for crash survival.

4. The addition of a new armored shell eliminates all design margins for safety within the major seat frame components and increases the probability of failure under crash impact.

RECOMMENDATIONS

It is recommended that:

1. The current seat frame be retrofitted structurally to withstand the following design ultimate load factors measured through the seat-occupant center of gravity:

Vertical	15G
Longitudinal (forward)	15G
Lateral	± 15G

2. Future design solutions for the UH-1 aircraft series include a systems engineering approach to the design of aircrew-protection systems; all tie-down points (floor, airframe, seat frame, et cetera) should be designed to consider the inertial effect of the armor under crash conditions.

3. The shoulder harness be recessed within the cargo floor to facilitate the in-flight removal of the seat and still to maintain a floor connection path for harness loads.

4. Energy-absorbing material be provided within the armored shell to attenuate vertical decelerations.

DISCUSSION

CRASH SURVIVAL SAFETY

The purpose of the entire seat and body restraint system is to provide occupant retention during crash conditions. The current UH-1D nylon-tubular frame seat has an excellent record of performance in this respect. Preliminary statistics, developed by the U. S. Army Board for Aviation Accident Research (USABAAR), on 109 survivable UH-1 accidents for the period 4 May 1961 to 12 November 1964 indicate that no back injuries were attributed to the UH-1D seat. In addition to the reduction of back injuries, the structural integrity maintained by this seat has given it an excellent record. The primary reason for this performance is due to the fact that the current seat carries none of the shoulder harness or lap belt tie-down loads. The shoulder harness and lap belt are attached to the floor structure. Therefore, the principal occupant inertia loads (neglecting skidding friction between the seat and occupant) are transferred to the restraint system. By transferring the loads to the floor, the structural requirements of the seat may be reduced.

The armored seat shell design involved the transfer of the shoulder harness reel from the floor to the back of the seat frame. The transfer of this component introduces new loads into the seat frame.

The existing UH-1D seat and frame (see Bell drawing 205-070-746) are designed to conform to the load requirements of MIL-S-5822, type A-10, except as follows:

1. Paragraph 3.4.3.3 is applicable except that the side load of 2,000 pounds shall be 3,000 pounds ultimate; no proof load is necessary.

2. Paragraph 3.4.3.4.2 is applicable except that the lap belt load of 1,440 pounds ultimate shall be 2,160 pounds ultimate and the shoulder harness load of 900 pounds ultimate shall be 1,350 pounds ultimate; no proof loads are necessary.

3. The strength requirements of paragraph 3.4.3 with the exceptions listed are applicable with the lap belt and shoulder harness attached to the floor structure at the points shown.

SHOULDER HARNESS STRENGTH FOR ARMORED SEAT

When the shoulder harness load is transferred to the seat frame, a redistribution of loading occurs. A large overturning moment is now introduced in the Z-X plane. This redistribution of loads contributes to a violation of the seat certification as outlined above. The requirement for the relocation of the shoulder harness reel was based on a tactical requirement; however, other alternatives are available:

1. Locate the shoulder harness reel below the floor line in a recessed well.

2. Provide dual reels located outside the track clearance envelopes.

Location of the shoulder harness in a recessed well would require a redesign of the production aircraft. Tooling and installation changes would be required, which would take a period of time for redevelopment. The use of dual inertia reels and an improved shoulder harness would contribute to improved lateral body restraint but would involve a design certification program. Of the two alternatives, recessing the existing reel is the best long-range solution, since it will not involve the purchase of new items of equipment.

DESIGN STRENGTH OF EXISTING HARNESS

Following are the current UH-1D harness components and their identifications and strengths:

Lap Belt: Type MD-2, AF Drawing 54H19651; 3-inch width by 45-inch length; 5,000-pound loop strength.

Shoulder Straps: Type G-1, AF Drawing 50D3770; 1.7-inch width; 1,800-pound total strength.

Inertia Reel: Type MA-6 (rate of extension); 4,000-pound ultimate strength.

The shoulder harness reel location contributes to a localized loading condition in the seat frame cross tubes. The effective column length of each cross tube is reduced (thereby increasing the allowable column load); but the fixity coefficient is changed because of the presence of the attachment bolts. A pull test of the shoulder harness reel was conducted, and the results are contained in Appendix II. Static side load test results indicated that the presence of the shoulder harness reel did not significantly weaken the cross tubes for this loading condition. However, the design margin for safety has been reduced to zero for the side load condition. The reduction in allowable load factor for the side load is not linear because the new load factor is based on structural failure.

SEAT BELT STRENGTH

Because of the relocation of the shoulder harness reel in the armored seat, a larger inertia load is transmitted into the seat. The seat belt design strength is rated at 5,000 pounds ultimate. After correcting for the compound tie angle of the belt, the belt ultimate side load was 940 pounds corresponding to a load factor of approximately 2.7G; and the belt ultimate forward load was 3,060 pounds corresponding to a load factor of approximately 8.75G.

These allowable maximum loads and load factors are based upon the use of a 200-pound occupant and a 150-pound seat. The failure loads are based upon a 100-percent sharing coefficient (either no restraint is provided by the seat or seat failure is assumed). These are conservative figures since load sharing occurs between the seat and the belt; the higher the sharing load in the belt, the lower the load in the seat and vice versa.

If seat failure occurs, it is highly probable that the seat belts will contribute to an attendant secondary failure. The seat belt strength is adequate from the standpoint of body restraint and webbing pressure levels. The inherent problem area is in the shoulder harness relocation.

The seat belt floor attachment fittings are well designed and have a large margin for safety through the floor connection bolts. The allowable bolt reaction load is 7,360 pounds for the seat belt attachment to the floor fitting. This, combined with the basic design strength of the floor fitting, provides adequate safety margins. The probability of belt failure exceeds that of floor fitting failure.

SEAT STRENGTH

The addition of an armored seat shell in the existing UH-1D frame decreases the allowable load factors (assuming a linear decrease) as shown in the following table.

TABLE I
UH-1D LOAD FACTORS

Ultimate Load	Nylon-Tubular Seat (G)	Armored Seat (G)
Forward	15	9.4
Side	15	9.4
Vertical	15	9.4

Note:
UH-1D tubular seat weight ≅ 30 pounds
UH-1D armored seat weight ≅ 150 pounds
Occupant weight ≅ 170 pounds

These load factors are only indicative of the effect of increased seat weight and do not reflect the maximum allowable load factors based on an internal stress solution. The structural analyses of the seat frame are presented in Appendix I and the static seat test results in Appendix II.

AREAS OF POTENTIAL FAILURE

The loading conditions were developed by using the seat manufacturer's drawings for the UH-1D seat (FSN 1680-052-4716) and by analyzing Bell Helicopter Company installation drawing 205-070-746. A parameterized loading condition was developed for forward and side load conditions. The vertical load condition was analyzed, and it was found that the maximum shear and moment conditions occurred with the forward load. The armor seat shell stiffness is so large that shell distortion was not considered. This effect was well supported in test, and all loads were assumed to be introduced through the composite seat and occupant center of gravity. By parameterizing the load solutions, it was possible to compute the maximum allowable internal stress for each member and to convert to the maximum allowable load. As a result of this analysis, weak linkage train members were identified; these areas of potential failure are discussed in the following sections under separate headings.

TRACK FAILURE

The procedure used for a plastic hinge analysis of the channel-track connections was conducted similarly to the one outlined on pages 32-34 of TRECOM (now USAAVLABS) Technical Report 63-81, "Crash Injury Evaluation, Personnel Restraint Systems Study, UH-1A and UH-1B Bell Iroquois Helicopters". The use of a track section known as the Bell Aircraft Standard Extrusion Number 40-033 reduces the critical bending section of the track. The track tie-down bolts were analyzed and found to be adequate in strength.

SIDE COLUMN FAILURE

When the column struts are moved outboard, an eccentric load is present in the column. The calculated allowable compression loads are large enough to provide for a no-failure condition. This was supported in the test results for the vertical load condition, after the side column struts had been relocated to facilitate the acceptance of the wider armor shell.

SEAT LEG FAILURE

The frame legs appear to be critical for the vertical and forward load conditions, and beam bending failures appear probable at the lower seat attachment point. During the vertical testing, a plastic failure occurred at this point. Both leg tubes failed in bending at the seat adjustment pin holes. The pin holes contributed to a stress concentration on the compression side of each beam.

SEAT CROSS TUBE FAILURE

The seat back cross tubes were investigated for compression and tension loads. The presence of the shoulder harness mount reduces the effective column length of each cross tube and affects the end fixity coefficient. For the side load condition, the compression columns are adequate. The addition of the shoulder harness mount did not detract from the stiffness of these columns under the side load test conditions.

SEAT BUCKET/FRAME CONNECTION FAILURE

The armored seat bucket attaches to the seat frame through 16 bolts. The shear, bending, and tension strength of this connection pattern was found to have a high margin for safety. If loads or stresses are combined, the connections will still be adequate up to the previous load factor conditions.

LOCALIZED CONNECTION FAILURES

The frame leg connections at the seat base should be strengthened, since a failure occurred in the channel track during the side load test. The seat leg connection fitting pulled through the channel because of combined shear and tension. The use of a beam cap in this area combined with a new connection fitting will increase the strength of the connection point.

REFERENCES

1. Crash Injury Evaluation, Personnel Restraint Systems Study, UH-1A and UH-1B Bell Iroquois Helicopters, TRECOM Technical Report 63-81, U. S. Army Aviation Materiel Laboratories,* Fort Eustis, Virginia, March 1964.

2. Alcoa Structural Handbook, Aluminim Company of America, Pittsburgh, Pennsylvania, 1960.

3. Strength of Metal Aircraft Elements, ANC-5 Bulletin, Revised Edition, U. S. Government Printing Office, Washington, D. C., March 1955.

4. Seat Pilot's Adjustable, Short Range Aircraft, Types A-8, A-9, A-10, and A-11, USAF Military Specification MIL-S-5822 (with Amendment 1), 15 August 1950.

5. Harnesses, Shoulder Safety, General Specification For, USAF Military Specification MIL-H-5364A, 16 October 1956.

*Formerly U. S. Army Transportation Research Command.

APPENDIX I

STRENGTH ANALYSIS OF UH-1D AIRCRAFT PERSONNEL RESTRAINT SYSTEM

The manufacturers' drawings used in developing the seat load data are shown in Table II.

SEAT LOAD ANALYSIS

Various seat and occupant weights (see Figure 5) were used in determining the load factors for a MIL-S-5822 type A-10 seat.

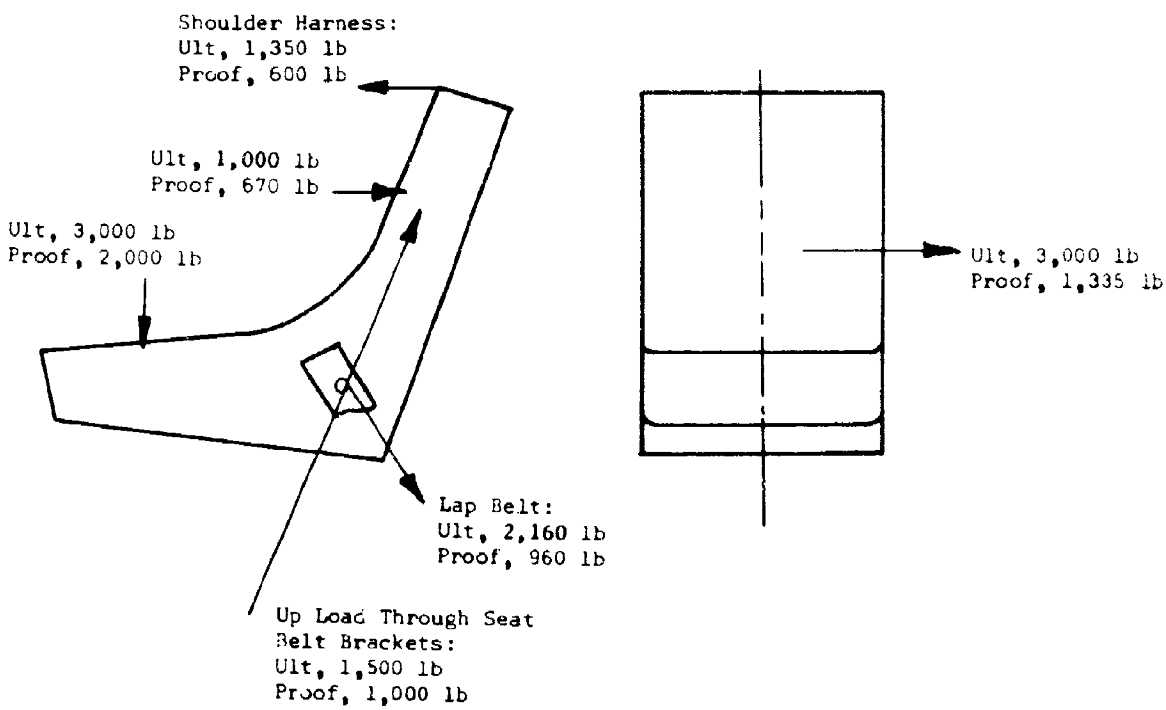

Figure 5. Seat and Occupant Weights Used in Developing Load Factors.

The load factors were developed by using the equations shown in the analyses on page 19.

TABLE II
DRAWINGS USED IN DEVELOPING SEAT LOAD DATA

Manufacturer	Drawing Number	Title
Alsco Incorporated	AL1018	Seat Assembly, Pilot and Copilot
Pacific Scientific Company	0106176-0	Reel Assembly, Shoulder Harness, Military
Bell Helicopter Company	40-033	Extrusion - Seat Track
	40-061	Extrusion - Fitting
	205-070-103	Fitting, Safety Belt, Cargo Floor
	205-070-104	Fitting, Inertia Reel, Cargo Floor
	205-070-733	Track Assembly, Forward, Pilot and Copilot Seat
	205-070-734	Track Aft, Pilot and Copilot Seat
	205-070-746	Seat Assembly, Pilot and Copilot
	205-070-747	Seat Pilot and Copilot Installation
	205-070-749	Lap Belt, Pilot and Copilot

Vertical load factor

$$V_{1f} = \frac{V_1}{W_s + W_o}$$

where

V_1 = vertical load, ultimate (pounds).

Lateral load factor

$$L_{1f} = \frac{L_1}{W_s + W_o}$$

where

L_1 = lateral load, ultimate (pounds).

Rearward load factor

$$R_{1f} = \frac{R_1}{W_s + W_o}$$

where

R_1 = rearward load, ultimate (pounds).

These load factors are shown graphically in Figures 6 and 7.

Figures 6 and 7 are based on an idealized load factor condition for the seat, which is linear with a noncoplanar load condition. Allowable load factors for combined loads will be less. They show the effect of increasing seat weight on the allowable ultimate load factor. By increasing the seat weight and maintaining the same loads, the allowable seat load factors are reduced.

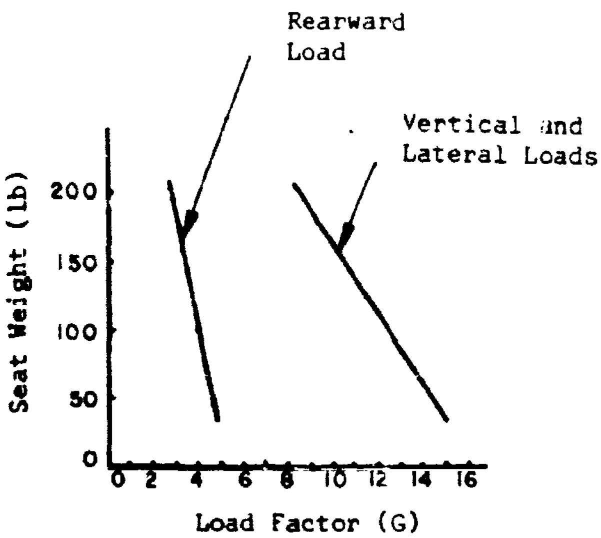

Figure 6. Load Factor With 168-Pound Occupant.

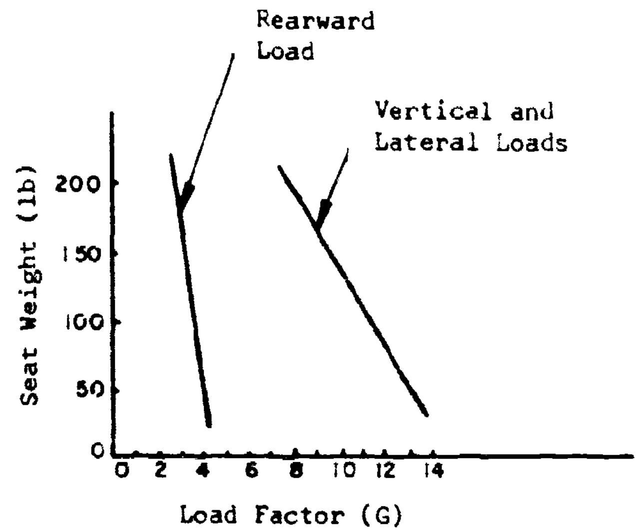

Figure 7. Load Factor With 195-Pound Occupant.

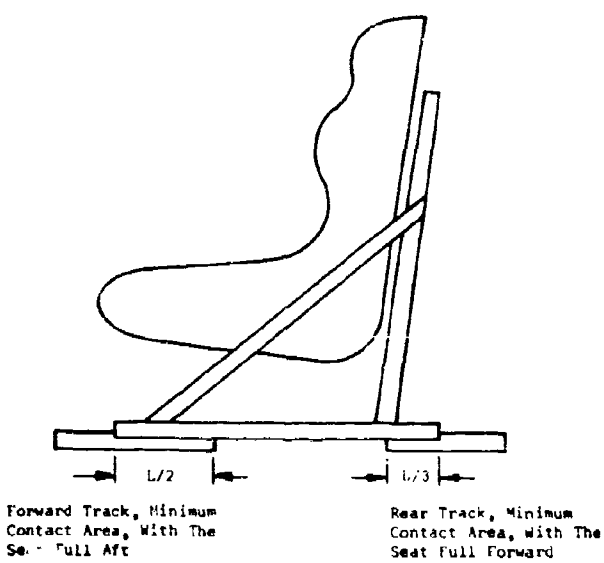

Figure 8. Seat and Track Position Schematic.

SEAT-TRACK ANALYSIS

The tie-down restraint chain for the seat consists of track-mounted rails that restrain the seat and the floor-mounted lap belt. The maximum reaction loads are computed through the occupant's center of gravity.

To determine the allowable design limit loads for the entire system, the track opening loads must be computed. The seat loads were treated as induced loads over the track areas, as shown in Figure 8.

Track-Channel Connection

The connection material was aluminum alloy 2024-T4 with a tensile yield strength of 42,000 psi.

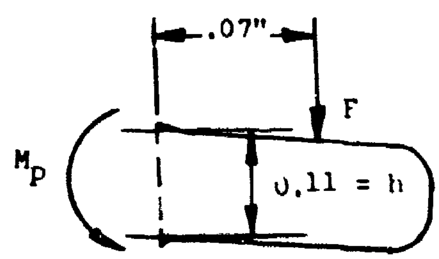

Figure 9. Track-Channel Free Body.

The plastic hinge moment, M_p, per inch of length is given by

$$M_p = \frac{F_{ty} h^2}{4} = \frac{(42,000)\ (0.11)^2}{4} = 127 \text{ inch-pounds per inch.}$$

The force per unit length, F, acting in one flange of the channel is given by

$$F = \frac{M_p}{0.07} = 1,815 \text{ pounds per inch.}$$

For the seat in the full forward position on the UH-1D, the track-channel overlap is 2.28 inches. Thus, in this position, the ultimate reaction, R_b, is

$$R_b = (2)\ (2.28)\ (F) = 8,280 \text{ pounds.}$$

For the seat in the full aft position on the UH-1D, the track-channel overlap is 4.625 inches. Thus, in this position the ultimate reaction R_a, is

$$R_a = (2)\ (4.625)\ (F) = 16,800 \text{ pounds.}$$

The rearward loading condition, R_a, was not analyzed further, as the forward and vertical load conditions are critical.

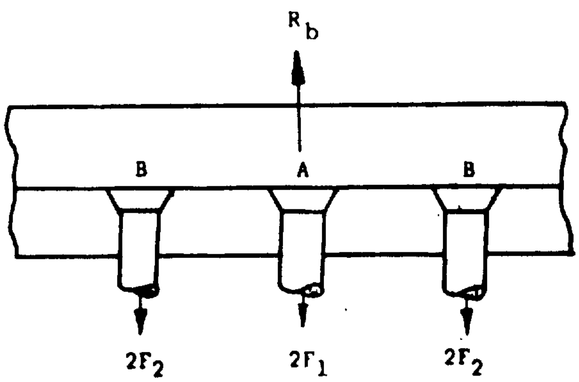

Figure 10. Seat Track Tie-Down.

Track Tie-Down

The critical position for the aft seat reaction, R_b (see Figure 10), is directly above one pair of tie-down bolts (A).

The adjacent bolts (B) may conservatively be assumed to sustain half the load of bolts (A).

Thus,

$$R_b = 4F_1$$

where

F_1 = ultimate tensile load for an AN-3 bolt (2,210 pounds).

Thus,

$$R_b = 4F_1 = 8,840 \text{ pounds.}$$

The above calculations show that the track-channel connection would fail before the track could be pulled from the floor.

A-FRAME ANALYSIS

An analysis of the A-frame for the seat will determine the maximum allowable horizontal and vertical forces, P_f and P_v, respectively, based on the track tie-down reactions, R_a and R_b, as determined previously. If horizontal force P_f is used,

$$\Sigma M_{R_b} = 0 = -P_f\,(20) + 16,800\,(16.38),$$

and

$$P_f = 13,750 \text{ pounds};$$

when

$$\Sigma M_{R_a} = 0 = -20P_f + 8,280\,(16.38),$$

$$P_f = 6,770 \text{ pounds}.$$

Thus, a horizontal force, P_f, in excess of 6,770 pounds will fail the A-frame at the aft track connection. Because the vertical load, P_v, moment arm is less than the forward load arm, the critical loading condition will be determined by P_f.

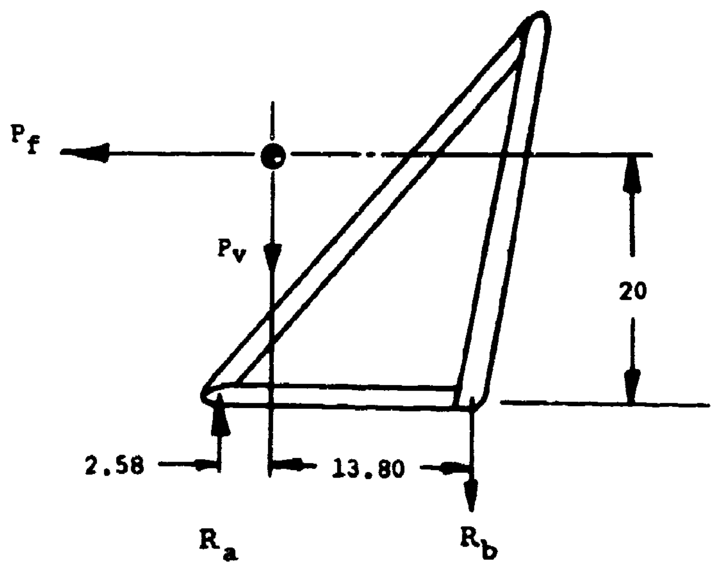

Figure 11. Side View of Seat Frame. (R_a = 16,800 pounds; R_b = 8,280 pounds.)

SIDE LOAD ANALYSIS FOR THE SEAT

In the side load analysis for the seat, it is assumed that:

1. Attachment moments are neglected.
2. No other loads are present in the structure.
3. Structure is in equilibrium.
4. Leg load restrains one-half of side load (neglecting column side load).

By reference to Figure 12, the side load analyses may be developed.

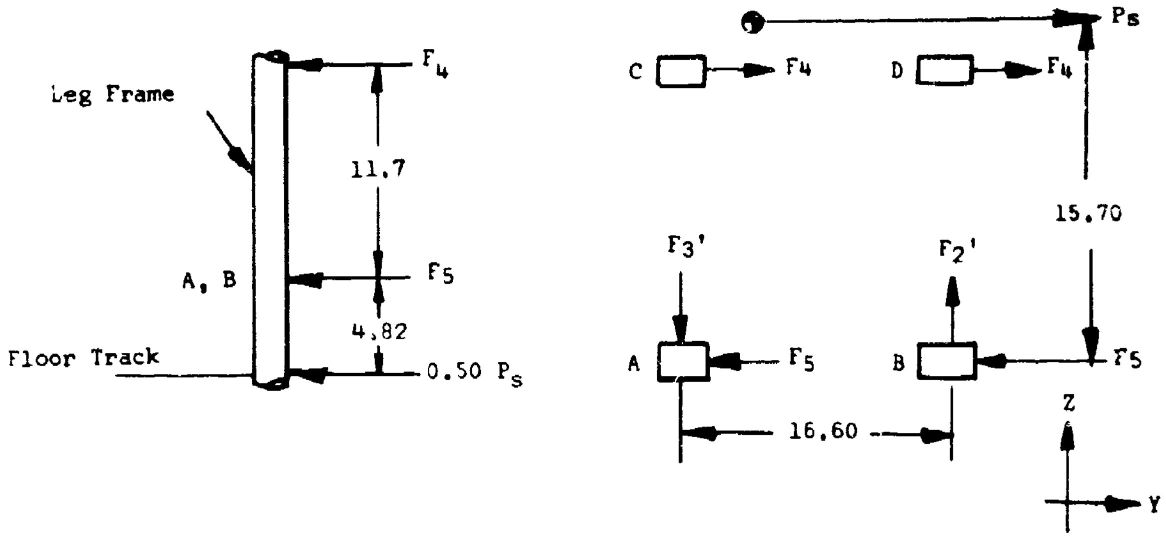

Figure 12. Rear View of Seat.

When moments for the seat leg are summated,

$$\Sigma M_{AB} \text{ (neglecting attachment moment) } = 0,$$

$$F_4 (11.7) = 0.50 P_s (4.82),$$

$$F_4 = 0.206 P_s.$$

When moments for the seat back are summated,

$$\Sigma M_B = 0 = F_3'(16.6) - 2F_4 (11.7) - P_s (15.7),$$

$$F_3' = 1.24P_s,$$

$$\Sigma F_y = 0 = 2F_4 + 2F_5 = P_s,$$

$$F_5 \quad 0.294P_s.$$

The presence of the side load will introduce an additional forward reaction load in $F_1' + F_2'$, as follows:

$$\Sigma M_{BD} = 0,$$

$$(F_1' + F_2')(16.6) = P_s (16.3),$$

$$F_1' + F_2' = 0.982 P_s.$$

If high torsional rigidity for the seat shell is assumed to be $F_1' \cong F_2'$, then,

$$F_1' = F_2' = 0.491P_s.$$

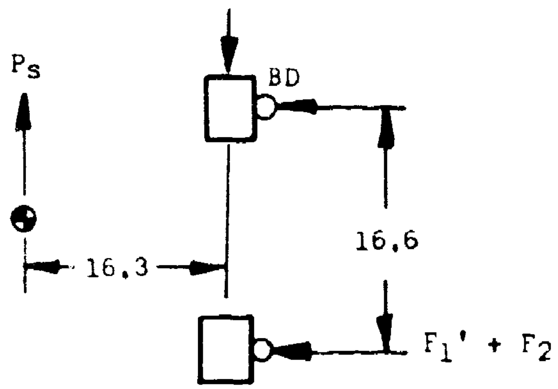

Figure 13. Top View of Seat.

Column Reaction Load due to Side Load Conditions

By applying the reaction joint loads F_1' and F_2', the compressive load, C, may be determined by considering the left aft leg as a free body (see Figure 14).

If the moments are summed about point 0, the compressive force due to side loading in the forward seat leg is obtained as follows:

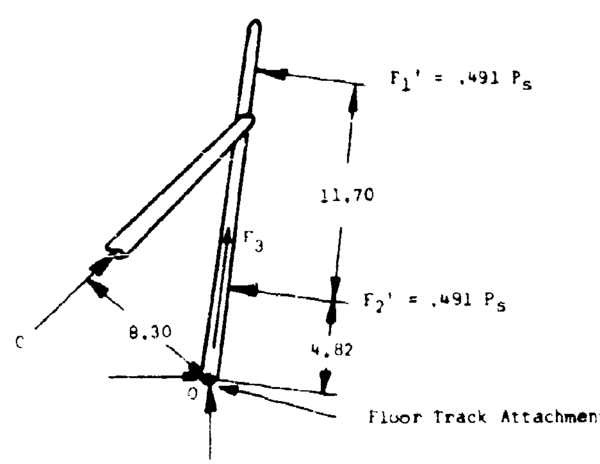

Figure 14. Free Body of Aft Leg.

$$\Sigma M_o = 0,$$

$$C (8.30) = F_2'(4.82) + F_1'(16.52),$$

$$C = 1.26 P_s.$$

FORWARD LOAD ANALYSIS OF THE SEAT

Figure 15 shows the forward load diagram.

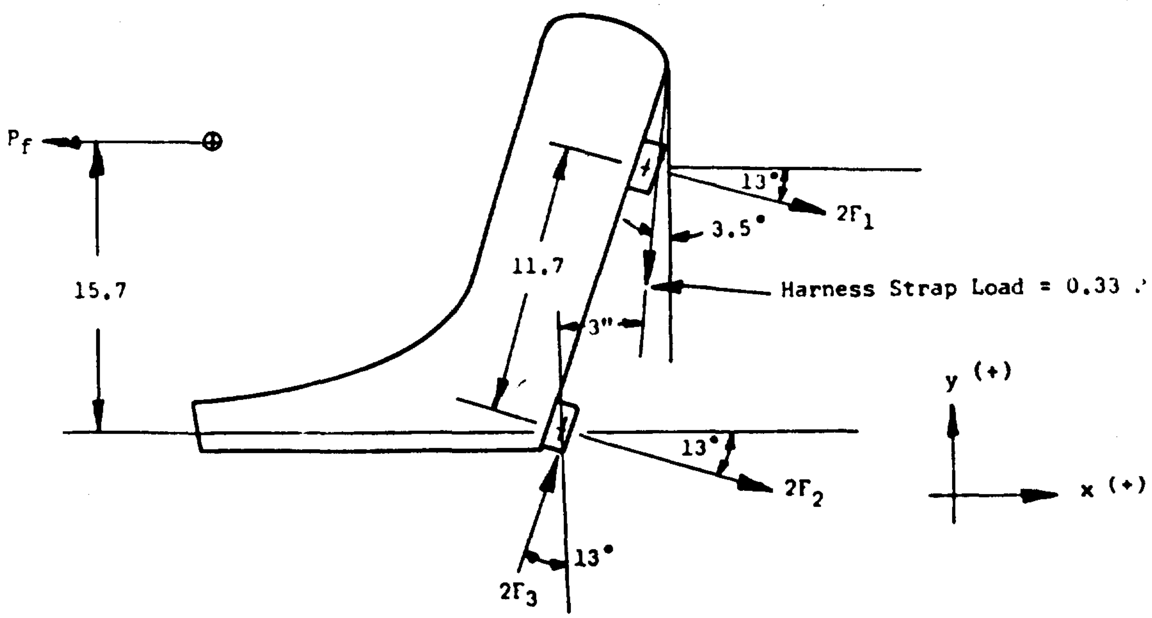

Figure 15. Forward Load Diagram.

Compressive Load ir Forward Leg

Since the displacement of the center of mass has been assumed to be in the direction of the inertia force on the occupant, this force may be transmitted along its line of action back to the original location of the center of mass. If moments are summated about F_3,

$$\Sigma M_{F_3} = 0 = 2F_1\ (11.7) - 15.7\ (P_f) + \cos 3.5\ (0.33P_f)\ (3.0),$$

$$F_1 = 0.630\ P_f.$$

If forces in X and Y direction are summated, then

$$F_2 = 0.17\ P_f,$$

$$F_3 = 0.274\ P_f$$

Track-Channel Connection

To evaluate the load transmitted from the carriage channel to the floor track, the leg frame is depicted as a free body diagram with the seat shown in the full-up position (see Figure 16).

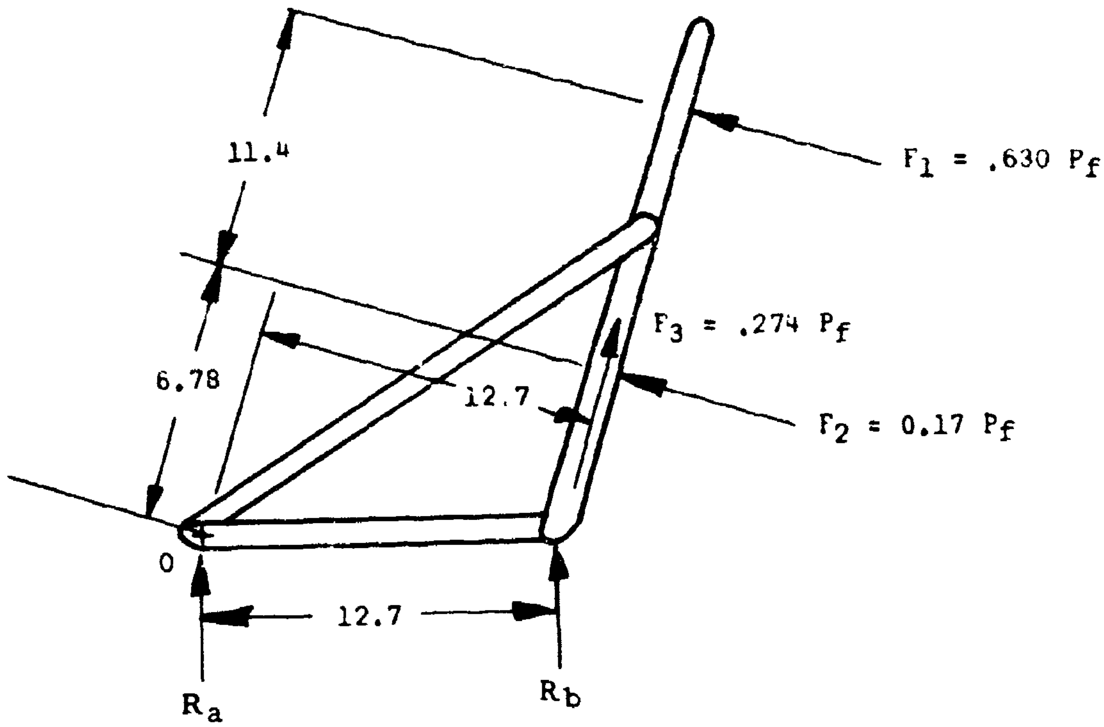

Figure 16. R_b Seat Frame, Full-Up Position.

If moments are summated about point 0,

$$R_b = 1.26\ P_f.$$

To ensure the track's not failing, it has been established that the maximum allowable load for R_b is 8,280 pounds. Therefore, P_f should not exceed approximately 6,570 pounds. Based on a maximum forward load, P_f, the maximum allowable loads for F_1, F_2, and F_3, are as follows:

$$F_1 = 4,140 \text{ pounds}$$

$$F_2 = 1,120 \text{ pounds}$$

$$F_3 = 1,800 \text{ pounds}$$

Figure 17 illustrates the left aft leg as a free body.

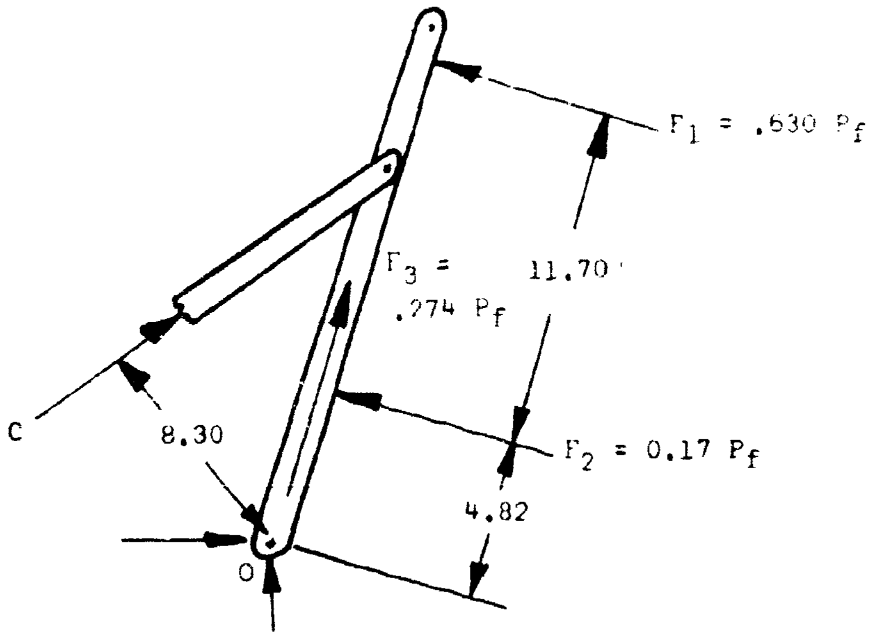

Figure 17. Free Body Of Leg.

If moments are summed about point 0, the compressive force due to forward loading in the forward seat leg is

$$C = 1.15\ P_f.$$

Connection at Top of Aft Seat Leg

If the compressive force, C, in the forward seat leg is resolved into components along and perpendicular to the aft seat leg, the free body diagram of the aft leg can be obtained (see Figure 18).

The force, T, which must be transmitted through the tension bolt at the top of the aft leg is as follows:

$$T_a = \cos 43.3^o\ C$$

$$T_a = 0.837\ P_f.$$

The tensile force, T, at the base of the aft seat leg is given by

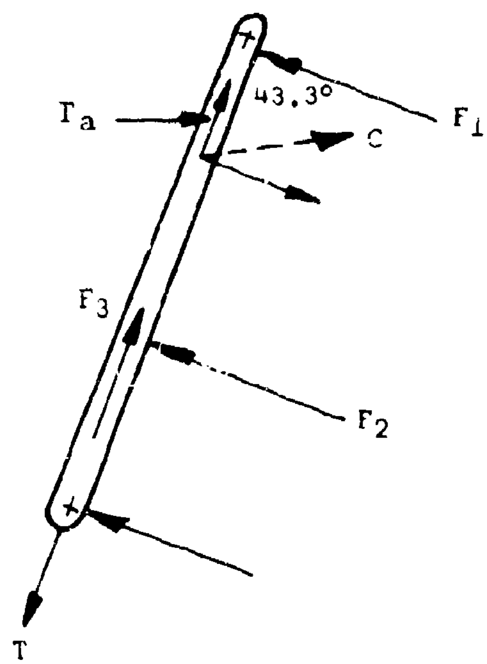

Figure 18. Connection Load Diagram.

$$T = T_a + F_3,$$

$$T = 1.11\ P_f.$$

BENDING IN AFT LEGS AS SHOWN BY COMPARISON DIAGRAMS FOR FORWARD AND SIDE LOADING

The purpose of this section is to provide a comparison of the beam bending and shear diagrams for the aft seat legs under each load condition. All loads were developed under separate analyses (see Figure 19).

If moment diagrams are compared, it can be seen that the maximum moment occurs in bending because of the forward load P_f.

The maximum allowable bending moment due to forward loading is

$$M = 2.97\ P_f.$$

For a 1.375-inch-diameter tube ($t \cong 0.061$) of 4130 steel,

$$S = 0.081$$

and

$$F_{b\ max} = 90,000\ \text{psi}.$$

Since

$$F_{b\ max} = \frac{M}{S} = \frac{2.97P_f}{0.081},$$

then

$$P_f = 2,460\ \text{pounds (one leg)}.$$

Therefore, the maximum forward load, P_f, for both legs is 4,920 pounds.

STRESS ANALYSIS SAFETY BELT FITTING, CARGO FLOOR

Information shown on Bell Helicopter Company drawing 40-061, which includes the material description and other parameters, was used when Figure 20 was developed (see page 30).

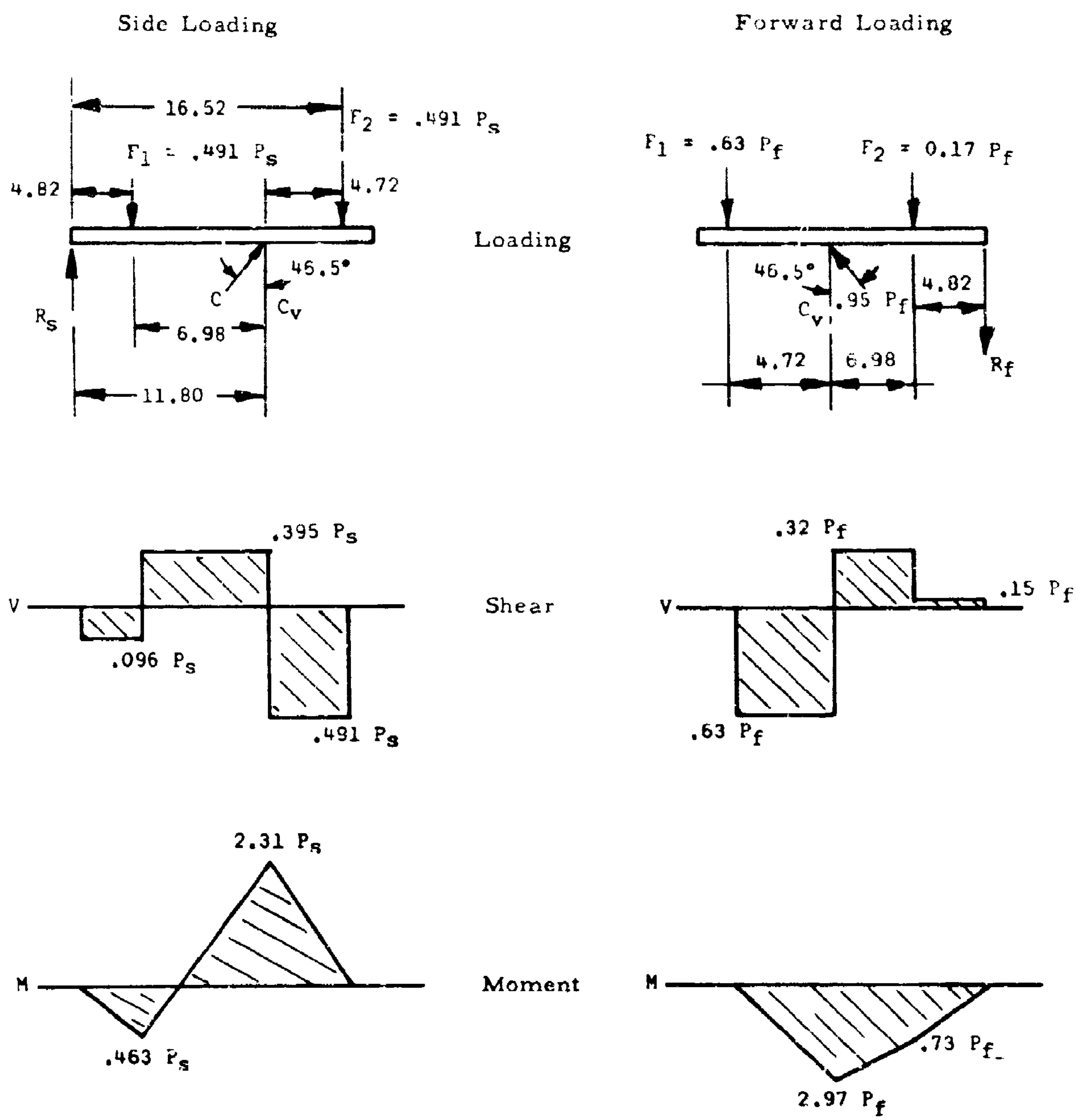

Fig re 19. Bending Shear and Load Diagrams for Aft Legs.

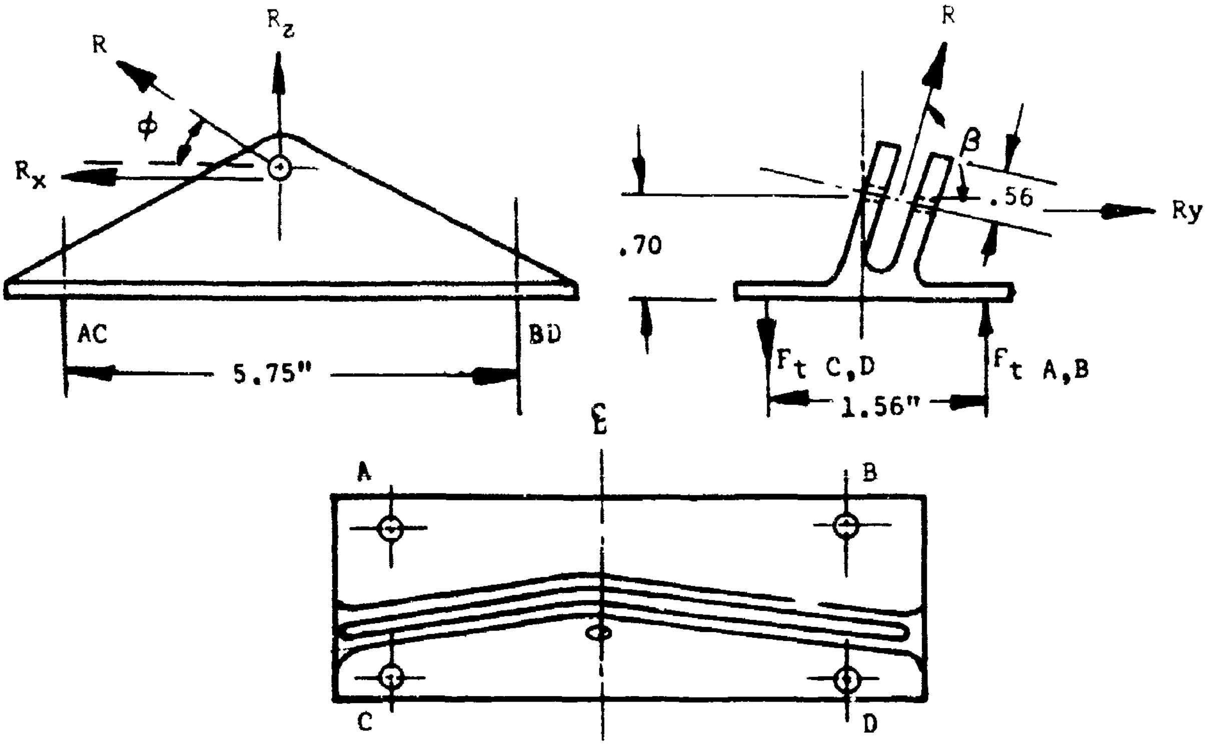

Figure 20. Safety Belt Fitting. (β = rotation angle = 72.50; ϕ = direction angle measured in the plane of rotation = 40°.)

If the maximum seat belt reaction is reduced,

$$R_x = R \cos \phi,$$

$$R_y = R \sin \phi \cos \beta,$$

and

$$R_z = R \sin \phi \sin \beta.$$

Tensile Bolt Loads

The incremental tensile loads in L nd D due to R_x are given by $\Sigma M_{AC} = 0$. If it is assumed that

$$F_{Btx} = F_{Dtx},$$

$$F_{Atx} = F_{Ctx},$$

and

$$F_z = 0,$$

then

$$\Delta F_{Btx} = \left[R_x \frac{0.70}{5.75} + R_z (.5)\right] (0.5).$$

To determine the maximum reaction load, the equations for R_x and R_z are substituted, and

$$\Delta F_{Btx} = 0.199R.$$

For incremental tensile loads about CD due to R_y, the $\Sigma M_{CD} = 0$.

If it is assumed that

$$F_{Aty} = F_{Bty},$$

then

$$\Delta F_{Dty} = \Delta F_{Bty} = 0.613R.$$

The critical bolt in tension is D, since both incremental tension loads may be added. The relationship for the combined load, F_{Dt}, is given by

$$F_{Dt} = F_{Bt} = \Delta F_{Btx} + \Delta F_{Bty} = 0.812R.$$

Therefore, the maximum allowable tensile load equation is

$$F_{Dt} = 0.812R.$$

If it is assumed that the shear loads are equally distributed between each bolt, then

$$F_{Ds} = 1/4 \ (R_x + R_y)$$

and substituting for R,

$$F_{Ds} = 0.197R.$$

If the AN-3 values for shear and tensile loads are used,

$$R_{max} = \frac{F_{Ds}}{0.197} = 10,800 \text{ pounds},$$

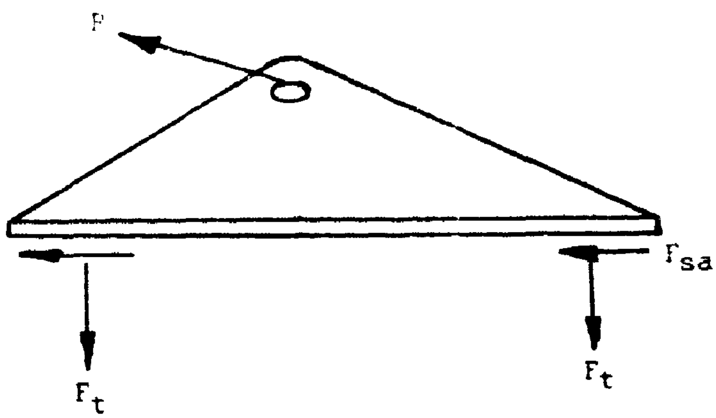

Figure 22. Tension and Shear Capacity, Seat Belt Fitting.

SEAT BELT ALLOWABLE LOAD

The purpose of this section is to analyze the maximum allowable seat belt strength levels for various load conditions (see Figure 23).

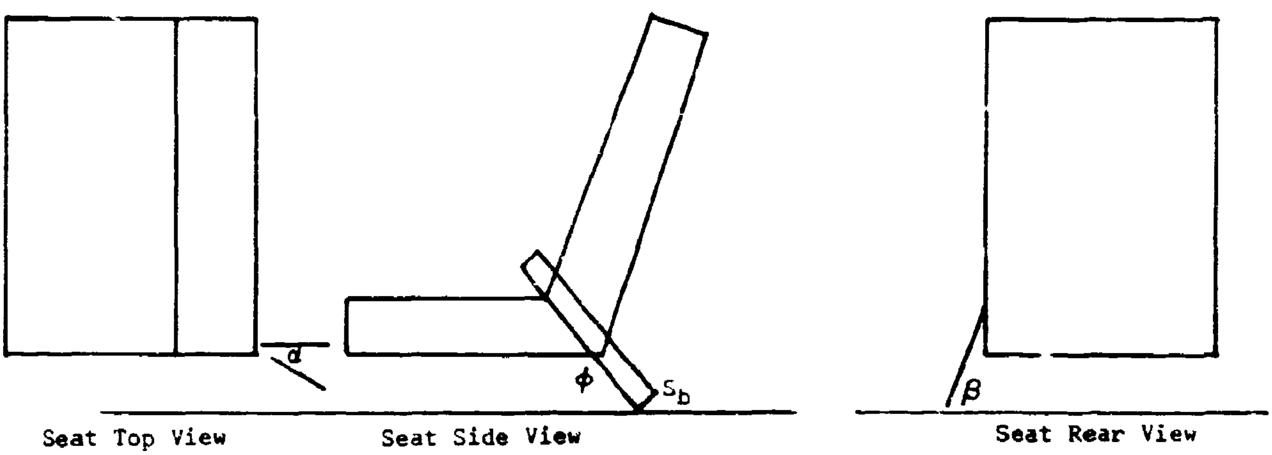

Figure 23. Angular Schematic for Seat Belt.

Forward Load Analysis

Where

$$\alpha = 30^\circ,$$

$$\phi = 45^\circ,$$

$$\beta = 73^\circ,$$

$$S_{b\ max} = \text{maximum (tensile load)} \cos \phi \ \cos \alpha$$

and

$$S_{b\ max} = 3,060 \text{ pounds.}$$

If a seat resistance of approximately 40 percent is assumed for a new seat,

$$P_f \text{ allowable} = 3,060 + 0.40 \ P_f \text{ allowable},$$

so that

$$P_f \text{ allowable} = \frac{3,060}{0.6}.$$

Then,

$$L_f = \frac{3,060}{200(0.6)} = 15.5G.$$

If the seat fails,

$$L_f = \frac{3,060}{350} = 8.75G.$$

<u>Side Load Analysis</u>

$$S_{b\ max} = \text{maximum (tensile load)} \cos \phi \ \cos \beta$$

and

$$S_{b\ max} = 940 \text{ pounds.}$$

If a seat resistance of approximately 40 percent is assumed for a new seat,

$$P_f \text{ allowable} = 0.940 + 0.40 \ P_f \text{ allowable},$$

so that

$$P_f \text{ allowable} = \frac{940}{0.6}.$$

Then,

$$L_f = \frac{940}{200(0.6)} = 7.81G.$$

If the seat fails,

$$L_f = \frac{940}{350} = 2.68G.$$

The above results are based on single-load conditions; combining the loads wil further reduce the load factors.

APPENDIX II

SUMMARY OF TESTS PERFORMED

(From Hardman Tool and Engineering Company Test Report)

INTRODUCTION

A static load test program was performed by Hardman Tool and Engineering Company on 26 and 27 April 1965, at their test facility at Los Angeles, California. The test specimens were four modified UH-1D armored helicopter seats. This work was contracted to Hardman Tool and Engineering Company by Aerojet-General Corporation in Azusa, California.

Extreme time limitations made a minimum load application and instrumentation program necessary.

The results indicate compliance of the seat to all requirements.

SCOPE

This test report delineates the criteria for usage and structural limits of the UH-1D helicopter seat.

PURPOSE

This test report provides for ease of selection of the performance capability of the subject seat.

REFERENCES

1. MIL-S-5822 (USAF) Amendment 1, dated 12 August 1957.

2. Bell Helicopter Company Drawing 205-070-746.

3. Aerojet-General Corporation UH-1D Armor Kit Installation Instructions.

4. Oral instructions of the representative of Aerojet-General Corporation, Mr. Dave Fernandez.

TEST METHODS

Equipment

1. The Hardman Tool and Engineering test rig consisting of a platform and a number of steel cross beams allowing installation of the load generating device in different positions as required

2. Hydraulic force generator incorporating adjustment for different ram speeds.

3. Hydraulic cylinder of 10,000-pound-tension capability.

4. "Dillon" dynamometer of 10,000-pound range.

5. "Federal" dial indicator of 1.00-inch range.

6. Tape measure.

Test Specimen

1. One fully armored UH-1D pilot seat.

2. One fully armored UH-1D copilot seat.

3. Two UH-1D lower seat structures.

Test Procedures

The test specimens were installed on the test platform as follows:

1. Test Number One, Downward Load Test. The test setup is shown in Figure 24. The downward load was applied to the seat bucket by a lever arrangement. The load application point was 11.50 inches forward of the seat reference point. The load was evenly distributed over the seat pan by a 0.50-inch-thick aluminum plate. The load was applied at a constant rate of 24 inches per minute. The instrumentation applied consisted of two dial indicators and one 10-foot tape measure. The 0.25-inch dial indicator measuring point was placed at the horizontal front tube measuring deflections at this point in the upward direction. The 1.00-inch dial indicator was installed to measure deflections on top of the back at the center in the forward direction. The measuring tape was attached to the same location as the 1.00-inch dial indicator in order to allow measurement to continue in excess of 1.00-inch forward deflection.

2. Test Number Two, Sideward Load Test. The test setup is shown in Figure 25. The required sideward load was directly applied to the back structure rather than as specified in References 1 and 2. The load application point was located 10.75 inches above the seat reference point. (The method and point of load application were requested by the representative of Aerojet-General Corporation.) Deflection readings were taken at the upper edge of the seat back as indicated by the arrow and at the horizontal front tube normal to the base plate.

3. Test Number Three, Forward Load Test. The test setup is shown in Figure 26. The required forward load was applied to the shoulder harness in the forward direction over the upper edge of the back at center. Deflection readings were taken at the upper edge of the chair at the center; the first inch deflection was measured with the 1.00-inch dial indicator, and all additional data were taken from the measuring tape. The second deflection reading was taken at the horizontal front tube normal to the test platform.

4. Test Number Four, Forward Load Test. The test setup is shown in Figure 27. The required forward load was applied to a special tool as shown in the photograph. The center of load application was located 10.5 inches above the seat reference point. Deflection readings were taken at two locations: (1) at the upper edge of the seat back at the center and (2) at the horizontal front tube at the center normal to the test platform.

RESULTS

Downward Load Test

Visual inspection after the test indicated failure of the vertical adjuster tubes. No failure of the armor was detectable. Deflection values for the two locations are shown in Table III on page 42.

Sideward Load Test

Failure occurred at 4800 pounds at the floor track rail. There was no failure of the armor detectable under this load. Deflection values for the two locations are shown in Table III.

Forward Load Test (Shoulder Harness)

Failure occurred in the lower structure at 900-pound horizontal forward load. The seat back deflected forward under this load to an extent that it was advisable to stop the test. There was no indication of detrimental armor failure under this load. Deflection values for the two locations are shown in Table III.

Forward Load Test (Through Seat Shell)

At 2500 pounds, side diagonal braces were bowing, and the front horizontal tube was bowing 45 degrees upward and rearward. Failure occurred at the lower structure at 2600 pounds. The seat pan deflected downward excessively under this load. There was no indication of armor failure under ultimate load. Deflection values for the two gage locations are shown in Table III.

CONCLUSION AND RECOMMENDATIONS

The foregoing described test program was conducted with the mutual understanding that only minimum instrumentation would be required and utilized. Furthermore, time was of extreme essence and therefore timesaving short cuts had to be used in conducting the program. Since no strength values from previously conducted tests were available, a comparison was not possible. Because of the added weight of the armor, conventional weight calculations could not be utilized. The upper section of the seat (the armored part) indicated excellent strength properties during the tests conducted. The lower (base part) indicates local weakness and should be reevaluated. A more sophisticated instrumentation package for future static and dynamic testing would be valuable.

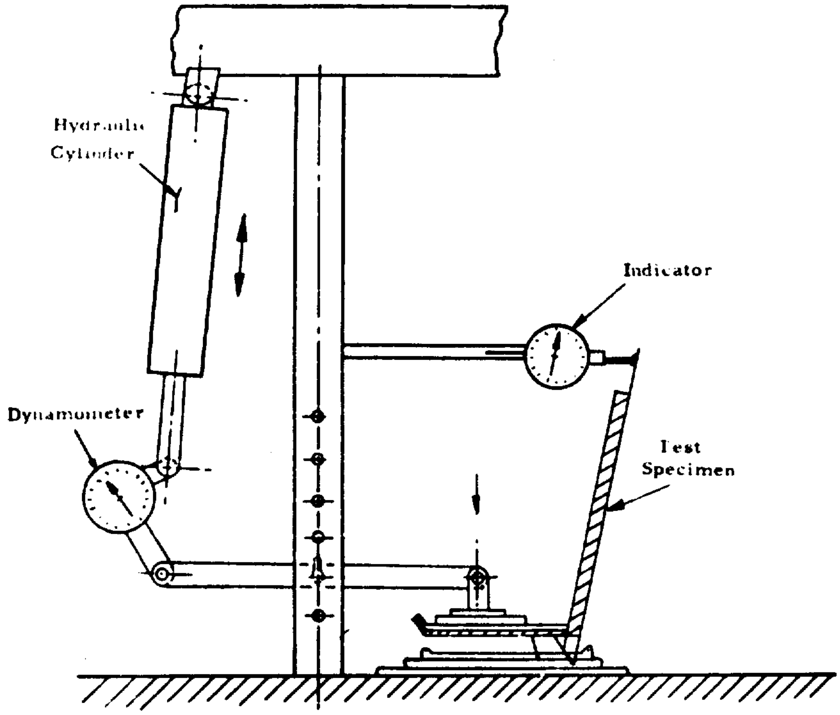

Figure 24. Schematic of Downward Load Test.

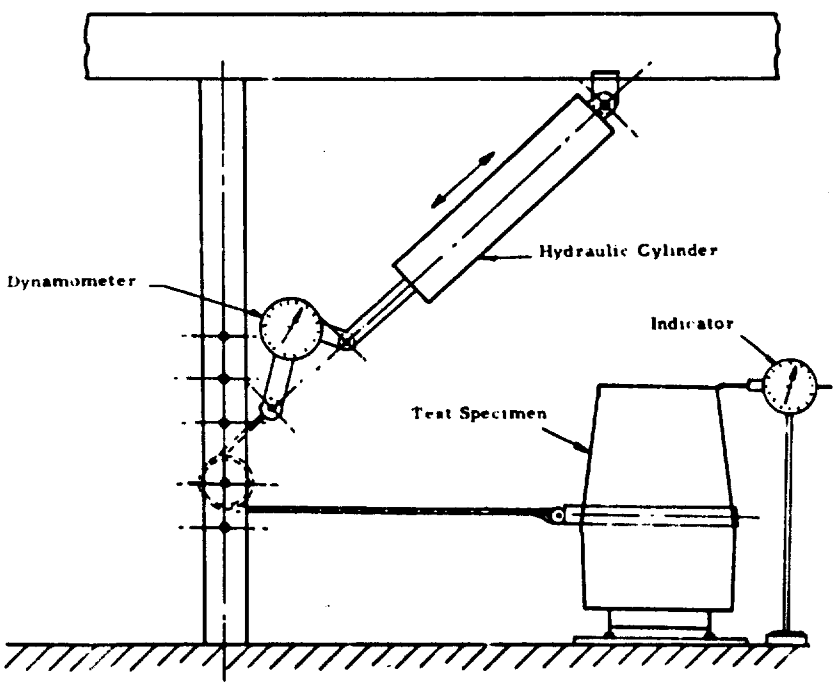

Figure 25. Schematic of Sideward Load Test.

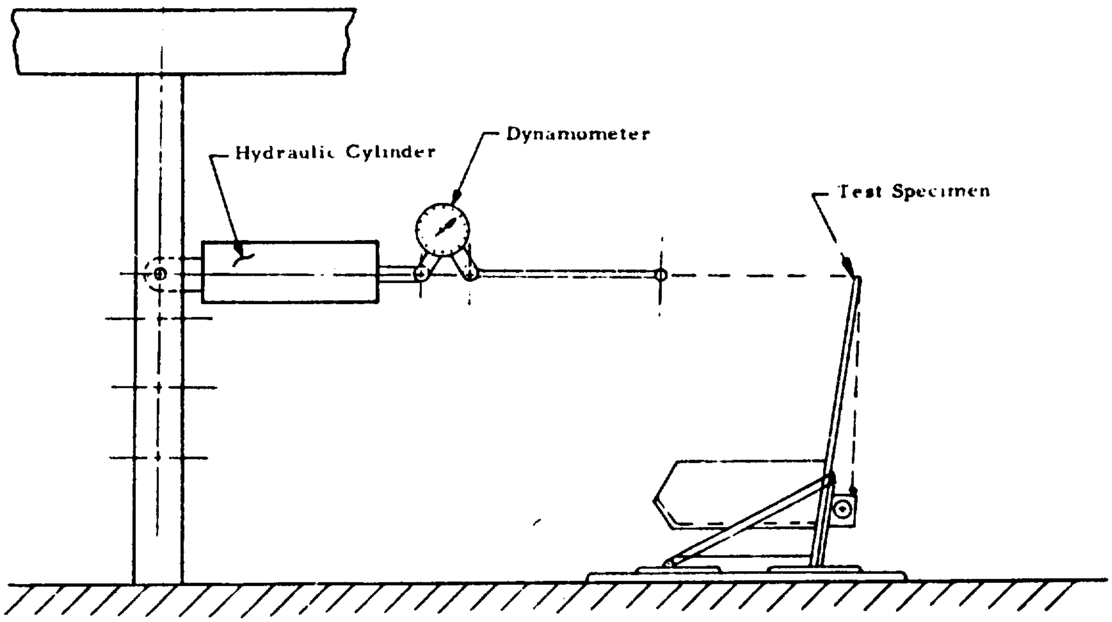

Figure 26. Schematic of Forward Load Test With Shoulder Harness.

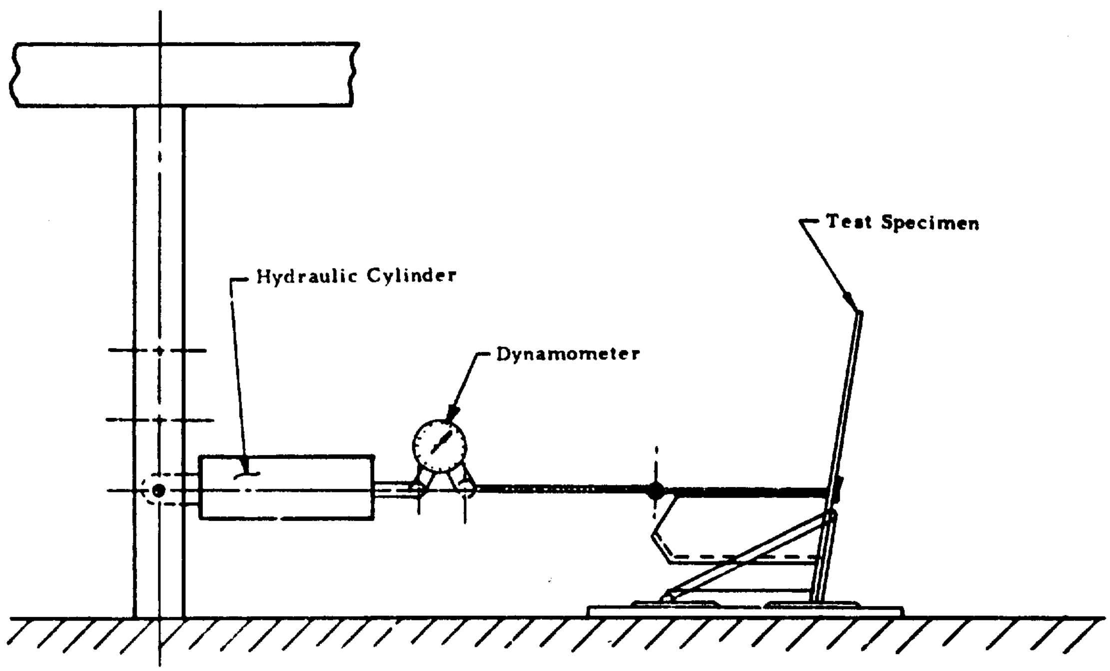

Figure 27. Schematic of Forward Load Test Through Seat Shell.

TABLE III
TEST DEFLECTION VALUES

Loads (lb)	Downward (in) Location		Sideward (in) Location		Forward (in) (Shoulder Harness) Location		Forward (in) (Seat Shell) Location	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
500	0.950	0.015	0.030	0.018	4.000	0.020	1.000	0.025
900[4]	---	---	---	---	8.500[1]	0.040	---	---
1,000	1.850	0.028	0.040	0.019	---	---	1.750	0.040
1,500	2.850	---	0.070	0.020	---	---	4.000	0.050
2,000[2]	3.750	0.050	0.090	0.022	---	---	4.750	0.065
2,500	4.670	0.056	1.500	0.025	---	---	5.250	0.065
2,600[4]	---	---	---	---	---	---	8.000	---
3,000[3]	5.620	---	2.000	0.030	---	---	---	---
3,500	6.570	0.063	2.250	0.035	---	---	---	---
4,000	7.500	0.075	2.500	0.040	---	---	---	---
4,500	---	---	4.000	0.043	---	---	---	---

[1]Permanent set 3.500 inches.
[2]Proof load.
[3]Ultimate load.
[4]Ultimate failure.

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13. ABSTRACT

This report contains the results of preliminary crash survival analyses of a UH-1D aircrew armor seat. It describes the reduced crashworthiness of the seat caused by the presence of the aircrew armor and develops suggestions for engineering changes to correct deficiencies. The data used in this study were developed from manufacturers' drawings, military specifications, and other sources.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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